



Modification of Jet Properties in the Nuclear Medium using π^0 -h Azimuthal Correlations

Nathan Grau, Iowa State University,
for the
PHENIX Collaboration

Outline

- Motivation for study of jet shapes in d+Au
- Extraction of jet shapes from 2-particle azimuthal correlations
- Comparison of results to p+p and d+Au of jet shapes
- Comparison with models

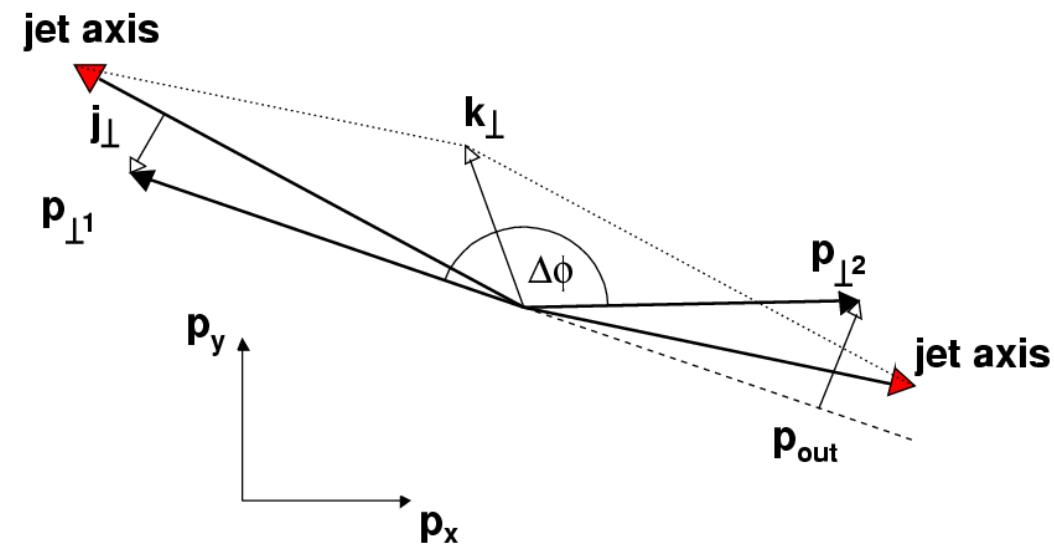


Jet Shape Observables

$\sqrt{\langle j_T^2 \rangle} \rightarrow$ Mean jet fragmentation p_T

$\sqrt{\langle k_T^2 \rangle} \rightarrow$ Mean net parton p_T

Quadrature sum of each parton k_T



Systematically study $p+p \rightarrow d+Au \rightarrow Au+Au$ evolution



Medium Modifications

p+p collisions: → vacuum fragmentation and broadening
no medium effects

$$\langle j_T^2 \rangle = \langle j_T^2 \rangle_{vacuum} + \langle j_T^2 \rangle_{F.S}$$

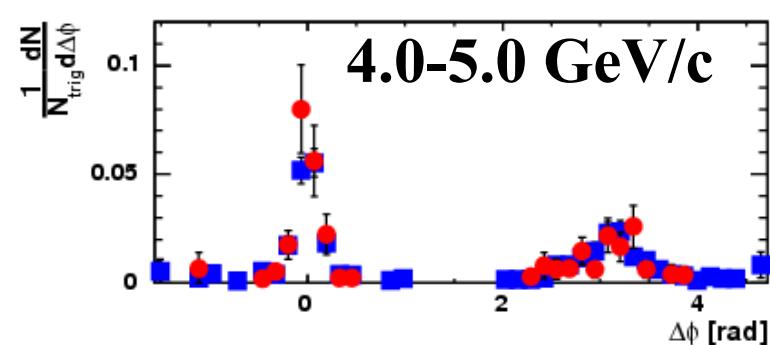
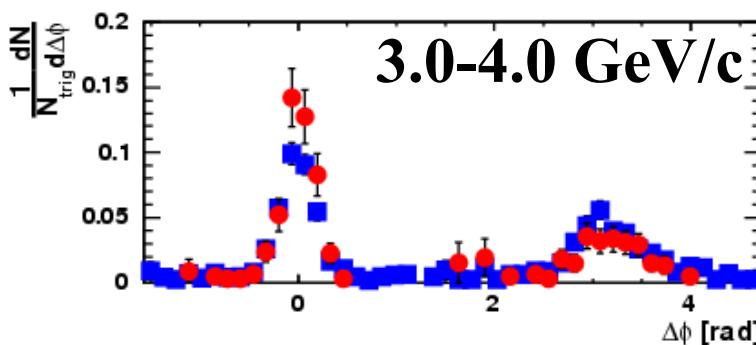
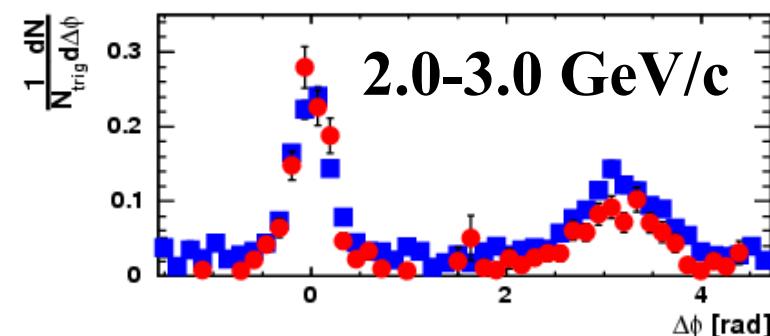
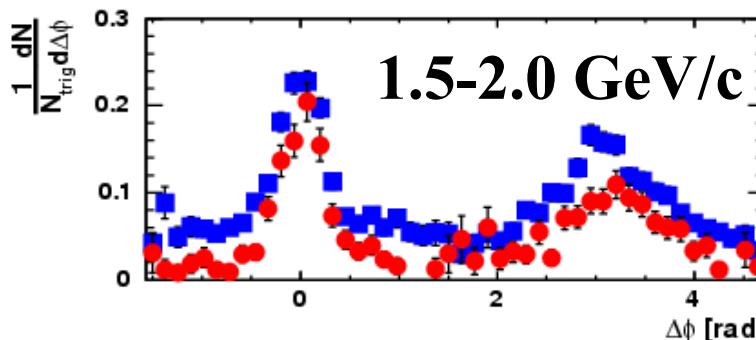
$$\langle k_T^2 \rangle = \langle k_T^2 \rangle_{vacuum} + \langle k_T^2 \rangle_{I.S} + \langle k_T^2 \rangle_{F.S}$$

d+Au collisions:
Initial state – multiple scattering
Final state – cold nuclear matter

Au+Au collisions:
Initial state – multiple scattering
Final state – QGP



Azimuthal Correlations



π^0 trigger 5-10 GeV/c, vary associated hadron
p+p – red
d+Au – blue



Extracting Quantities

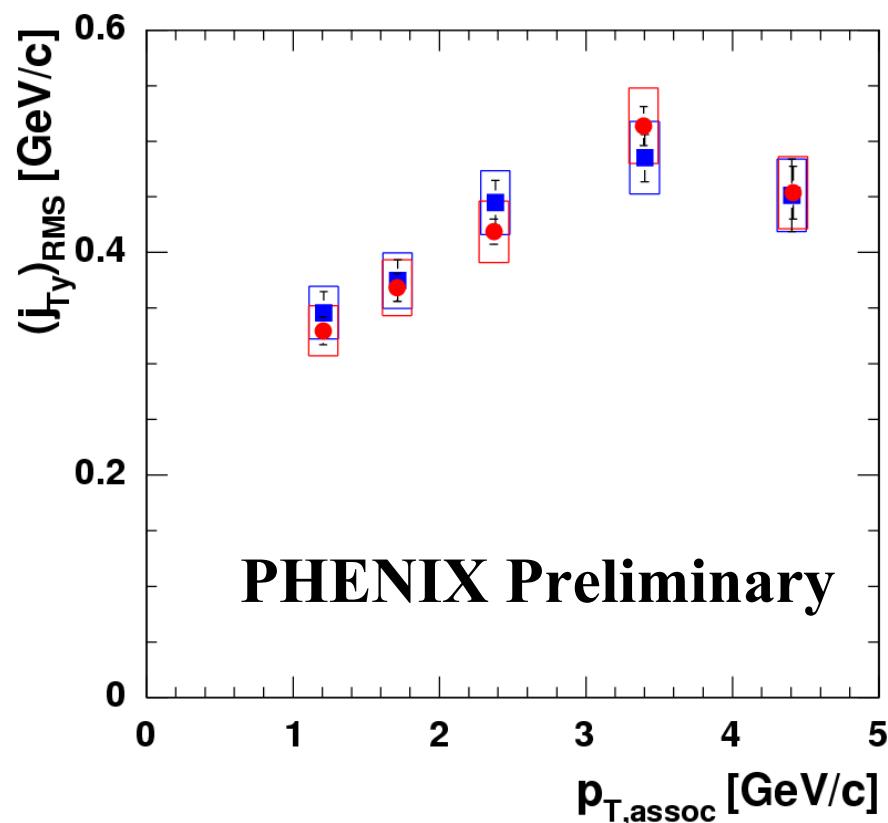
Jet properties extracted from azimuthal correlation shape

$$\frac{1}{N_{trig}} \frac{dN}{d\Delta\phi} = \frac{\text{background}}{\text{jet}} + \frac{S_N}{\sqrt{2\pi}\sigma_N} e^{\frac{-\Delta\phi^2}{2\sigma_N^2}} + \frac{S_F}{\sqrt{2\pi}\sigma_F} e^{\frac{-(\Delta\phi-\pi)^2}{2\sigma_F^2}}$$

- j_{Ty} extracted from the jet shape – σ_N
- $z_{trig} k_{Ty}$ extracted the di-jet shape & jet shape – σ_N, σ_F
 - $z_{trig} = p_{Ttrig}/p_{Tjet}$



Fragmentation Transverse Transverse Momentum

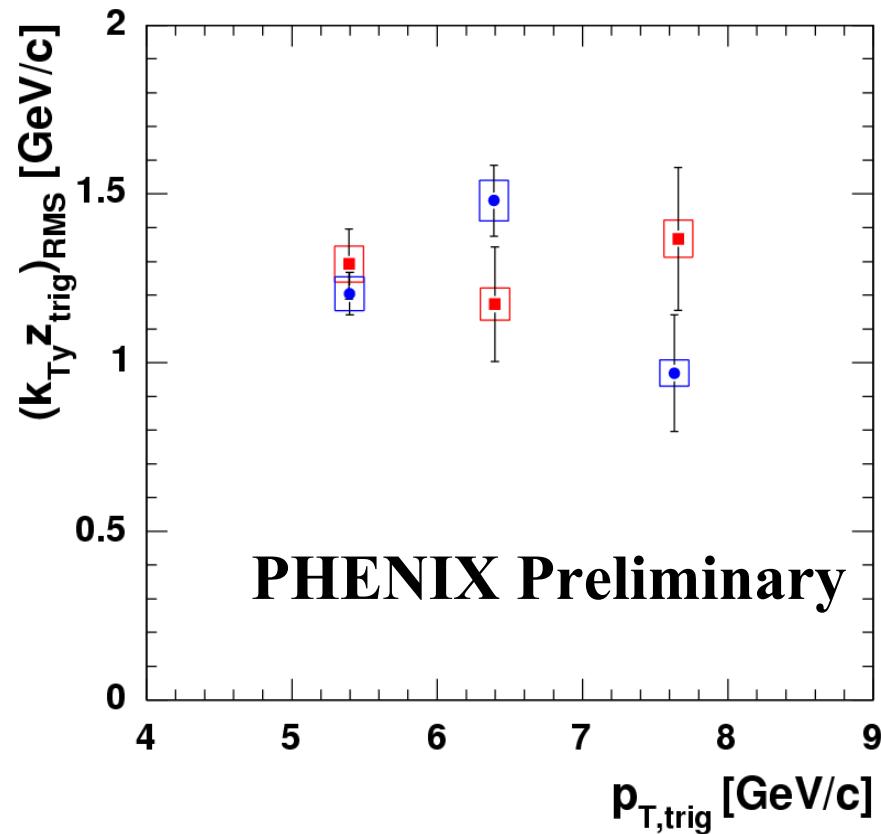


- π^0 trigger 5-10 GeV/c
- $p+p$ and $d+Au$ results are consistent
- Consistent with fragmentation outside of the cold medium



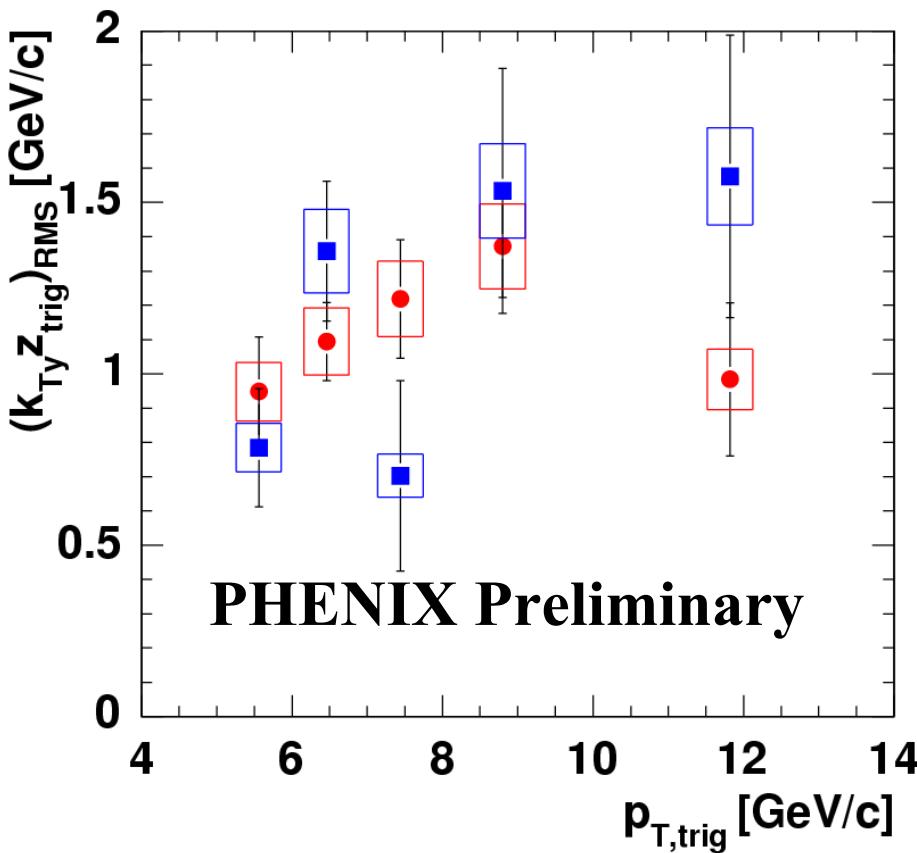
Net Parton Transverse Transverse Momentum

- associated hadron 2.5-5 GeV/c
- p+p and d+Au results are consistent





Other PHENIX Results



- Results from trigger $\pi^{+/-}$
- Similar results from $p+p$ and $d+Au$
- Combining PHENIX results in progress



<Z> Extraction

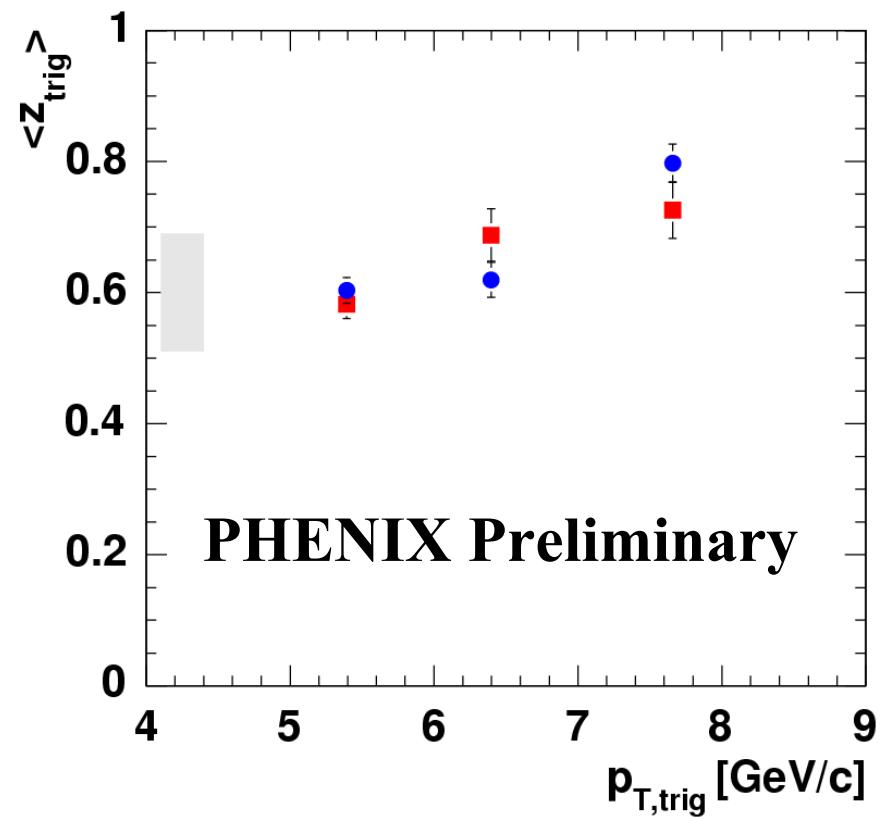
$$\langle z_{trig} \rangle = \frac{\int_{x_T}^1 \frac{dz}{z} z D(z) f_q(p_{T,trig}, p_{T,assoc})}{\int_{x_T}^1 \frac{dz}{z} D(z) f_q(p_{T,trig}, p_{T,assoc})}$$

- Need $D(z)$ – assume $D(z)$ from e^+e^- at $\sqrt{s} = 29$ GeV
MARKII PRD 37,1 (1988)
- Need $f_q(q_T)$ – final state parton distribution with the requirement of a second particle in the event
- Fit $f_q(q_T)$ to PHENIX π^0 spectra



$\langle z \rangle$

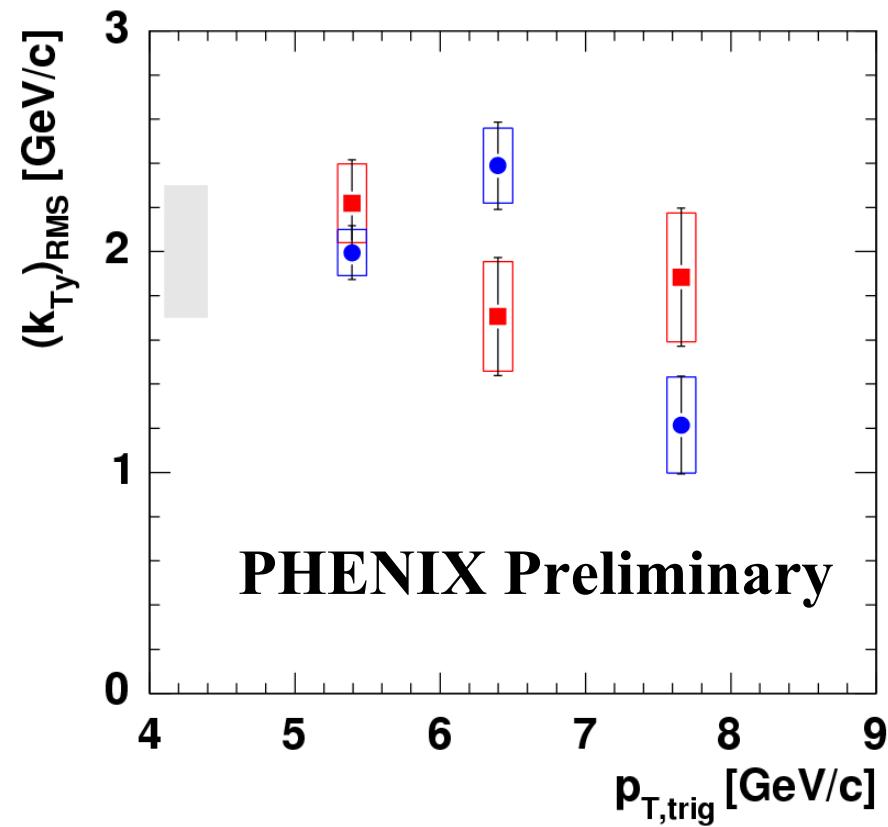
- Expected trend with $p_{T,\text{trig}}$
- $\langle z \rangle$ similar between p+p and d+Au
- Systematic error from variation of $D(z)$ shape





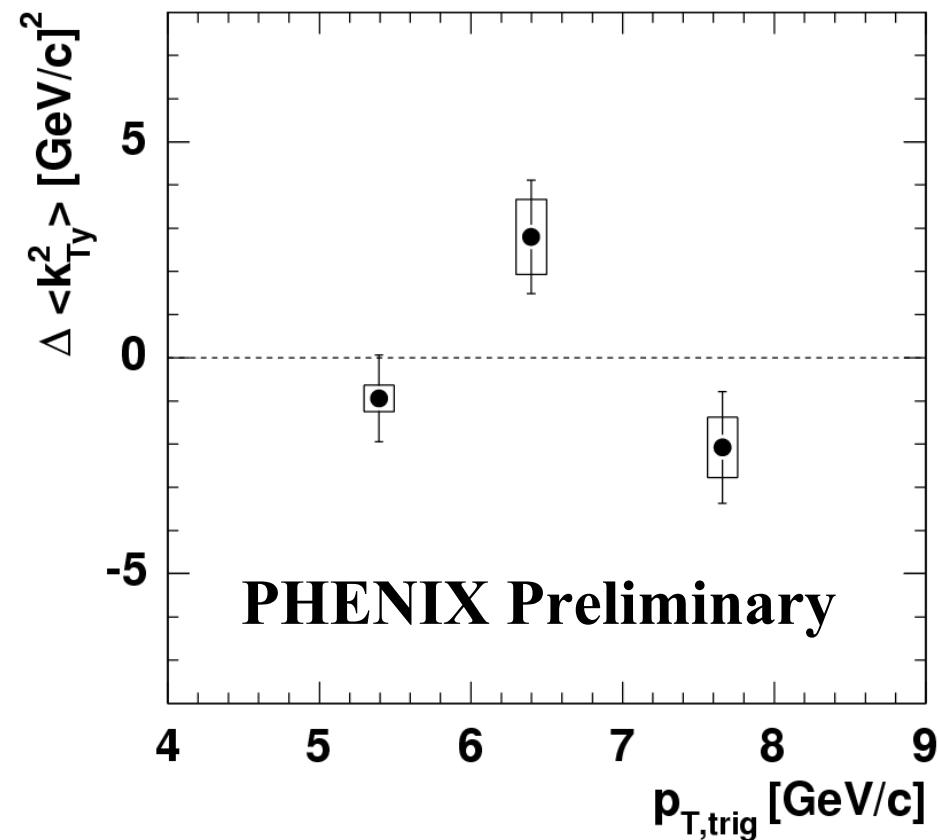
$(k_{Ty})_{RMS}$

- $(k_{Ty})_{RMS}$ consistent with flat vs. $p_{T,\text{trig}}$
- Consistent between p+p and d+Au
- Places limit on broadening





Difference between d+Au and d+Au and p+p



$$\Delta \langle k_{Ty}^2 \rangle = \langle k_{Ty}^2 \rangle_{d+Au} - \langle k_{Ty}^2 \rangle_{p+p}$$

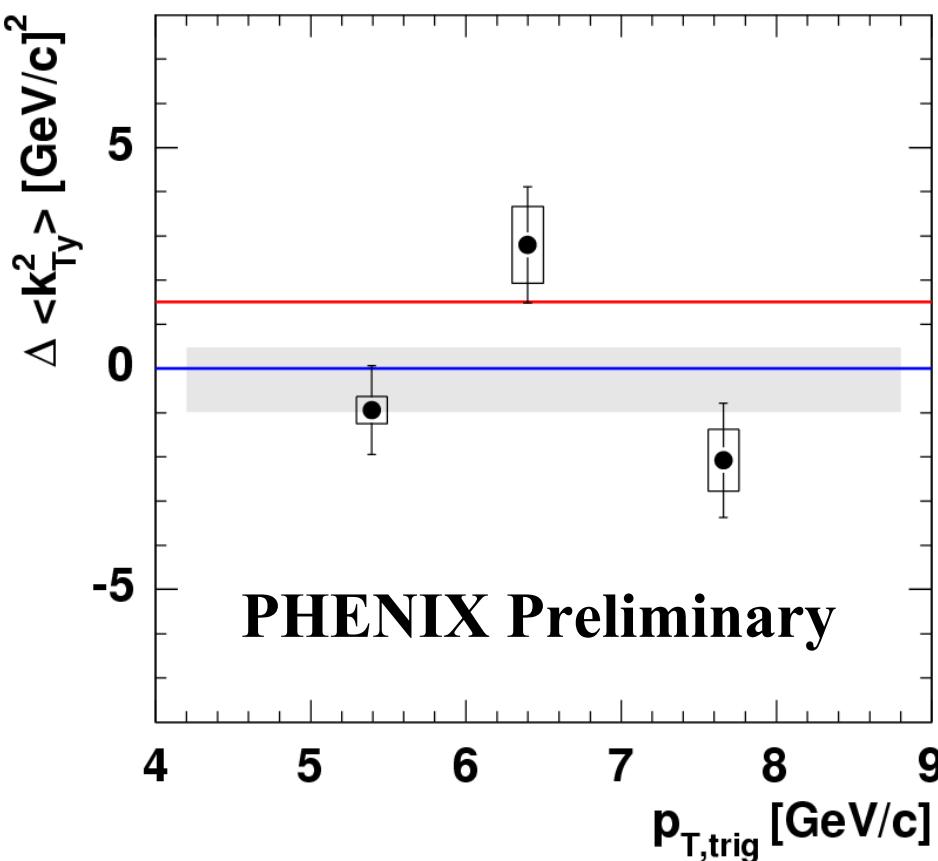
Sensitive to the broadening of di-jets due to multiple scattering

Weighted average:

$$\Delta \langle k_{Ty}^2 \rangle = -0.25 \pm 0.68(\text{stat.}) \pm 0.27(\text{sys.})$$



Model Comparison



- Grey band – weighted average of data
- Blue – recombination, Hwa and Yang **PRL 93, 082302 (2004)**
- Red – multiple scattering, Qiu and Vitev **PLB 570, 161 (2003)**
- Both reproduce R_{dAu}



Summary

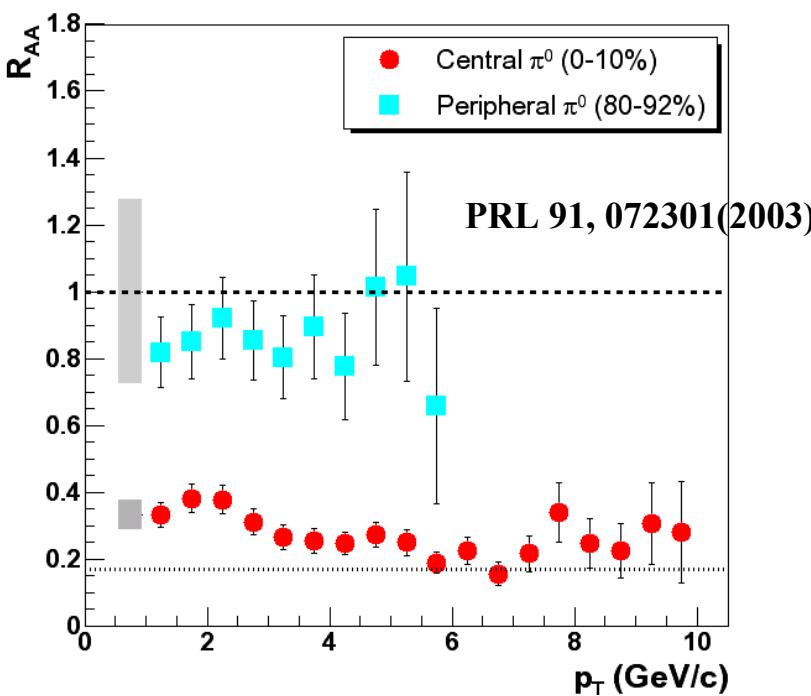
- Presented p+p and d+Au jet shape properties
- Jet shapes are consistent between p+p and d+Au
 - Similar to existing PHENIX results $h^{+/-}$, $\pi^{+/-}$
- Data constrain possible models of multiple scattering
 - High luminosity d+Au run



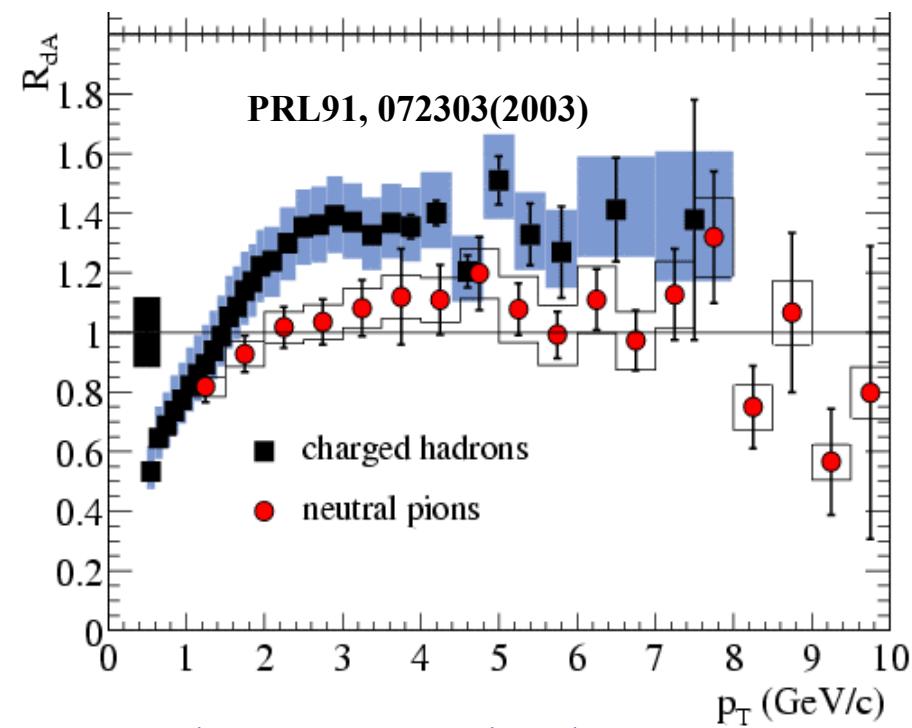
backup



High- p_T results



Suppression in Au+Au
collisions

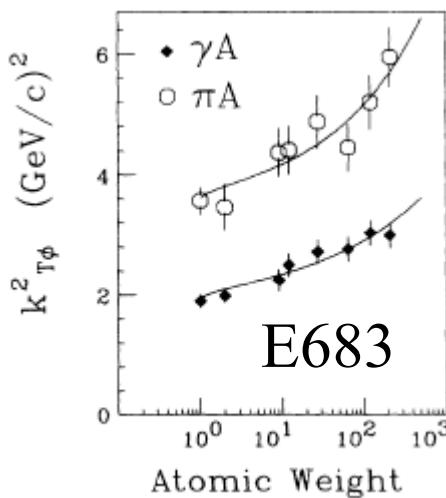


Enhancement in d+Au
collisions



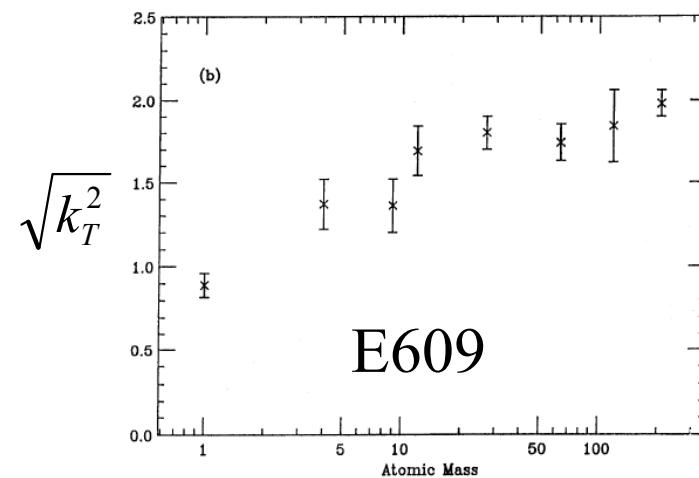
Broadening in p+A

$$\sqrt{s_{NN}} = 21 \text{ GeV}$$



PRL 72,15 (1994)

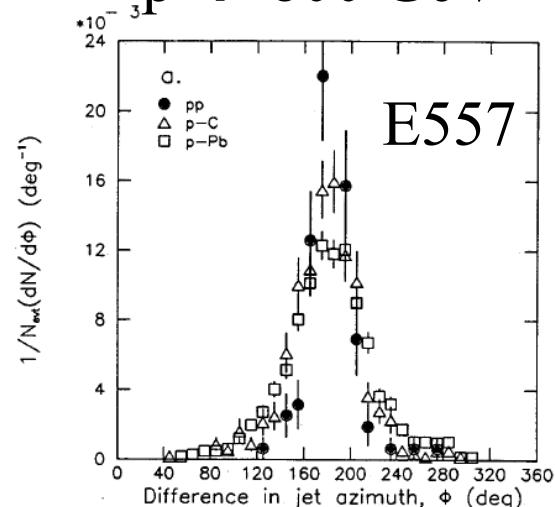
$$p \rightarrow 400 \text{ GeV}$$



E609

PLB 259 (1994)

$$p \rightarrow 800 \text{ GeV}$$



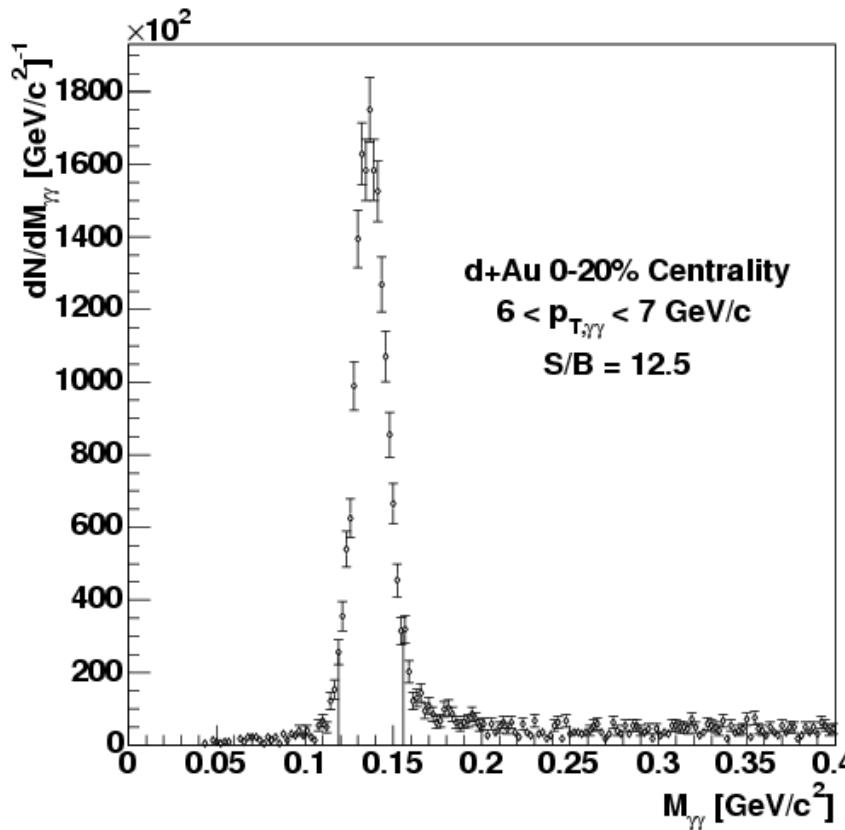
E557

PRD42 (1990)

Previous Fermilab fixed-target experiments have measured a sizable increase in the di-jet broadening in h+A collisions. RHIC data will extend the energy dependence of the effect.



Experimental Method



- Instead of Jet reconstruction – use a high- p_T trigger particle
- Lvl-1 EmCal-RICH trigger
 - Large increase in photon statistics
- Excellent π^0 detection
 - S/B $\sim 10-20$ for $\pi^0 > 5 \text{ GeV}$



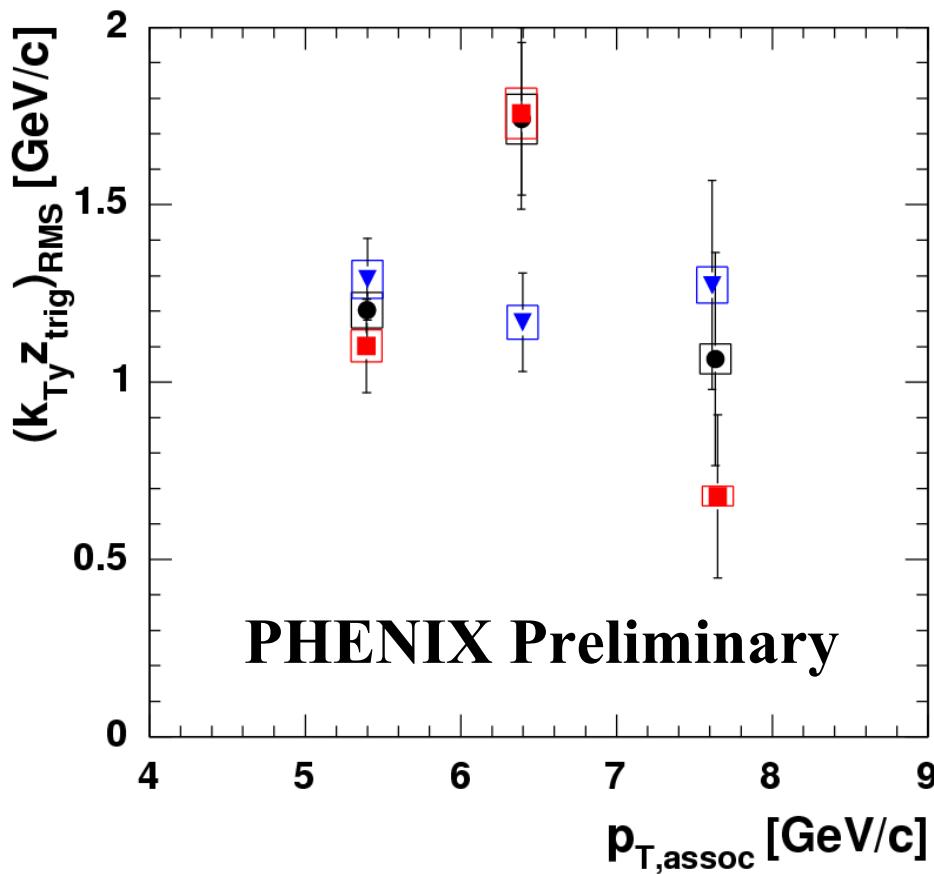
Detailed jt, kt formulae

$$(j_{Ty})_{RMS} = \sigma_N \frac{\langle p_{T,\pi^0} \rangle \langle p_{T,h} \rangle}{\sqrt{\langle p_{T,\pi^0} \rangle^2 + \langle p_{T,h} \rangle^2}}$$

$$(k_{Ty} z_{trig})_{RMS} = \frac{\langle p_{T,\pi^0} \rangle}{\sqrt{2}} \sqrt{\sin^2 \sigma_F - \left(1 + \frac{\langle p_{T,h} \rangle^2}{\langle p_{T,\pi^0} \rangle^2} \right) \frac{(j_{Ty})_{RMS}^2}{\langle p_{T,h} \rangle^2}}$$



Centrality Dependence



Black circles – 0-20%

Red squares – 20-40%

Blue Triangles – 40-88%

No clear centrality trend.